UNIVERSITY OF ILLINOIS BULLETIN

ISSUED TWICE A WEEK

Vol. XXXIV March 26, 1937 No. 60

[Entered as second-class matter December 11, 1912, at the post office at Urbana, Illinois, under the Act of August 24, 1912. Acceptance for mailing at the special rate of postage provided for in section 1103, Act of October 3, 1917, authorized July 31, 1918.]

AN INVESTIGATION OF STUDENT STUDY LIGHTING

BY

JOHN O. KRAEHENBUEHL

CIRCULAR No. 28

ENGINEERING EXPERIMENT STATION

PUBLISHED BY THE UNIVERSITY OF ILLINOIS, URBANA

PRICE: FORTY CENTS

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4000—3-37—11585

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CONTENTS

AN INVESTIGATION OF STUDENT STUDY LIGHTING

I. A Survey of Student Study Lighting at the University of Illinois*

1. *General Statement.*—In the school year 1933-34, the University of Illinois, with other schools, was requested by the Industrial and School Lighting Committee of the Illuminating Engineering Society, through a sub-committee of which Mr. W. F. Little acted as chairman, to conduct a survey of the lighting conditions prevalent in student study rooms and at student study desks. A preliminary survey was made as a special problem in illumination, and data were compiled for the committee.

This initial survey at Illinois indicated that the lighting was very poor and of such a nature that resultant eye strain with its accompanying secondary results might be expected. On the basis of the data obtained during this survey, the Physical Plant Department found it advisable to install new lighting equipment in those dormitories which are under the supervision of the University, and the new specified study lamp of the Illumination Engineering Society was installed in all the rooms.

Since the initial investigation covered only a small portion (about three per cent) of the study surfaces used by students, and since, also, funds were available under the National Youth Administration for student aid, a more comprehensive study of the problem was undertaken using a sample of larger proportions.

In the school year 1934-35, a trained organization of students, operating in teams of two, made night surveys of the study surfaces and study rooms of students in all divisions of housing at the University. This material was assembled and tabulated, and the general results of the survey are given in the following paragraphs.

Acknowledgment is made of the valuable service rendered by the students conducting and tabulating the survey, and of the hearty coöperation experienced in the making of accurate records of the actual conditions found in fraternity, sorority, independent, and University dormitory rooms. Acknowledgment is also made of the coöperation of those in charge of the various housing divisions, when the students requested permission to make lighting surveys.

*As it is believed that complete details of this investigation would be of interest to relatively few persons, only the general results are given; more detailed information may be obtained by those interested by application to the Engineering Experiment Station.

2. *Survey Procedure.*—The survey groups were formed of two individuals, the leader, an upper classman, and the assistant, a freshman. The leader of the survey group had received special instruction in lighting survey work and had had experience in making lighting surveys. The students were so trained before making surveys for record that it is possible to state that the survey may be considered reliable and accurate within the limitations of such work.

Each group was equipped with a survey kit which contained a 50-foot tape, a 6-foot folding rule, a color chart, an equipment classification chart, a reflection gauge, and a foot-candle meter (cell type), also survey forms, pencils, scale, and straight-edge. This kit was assigned to the leader who also supervised such replenishing as was necessary. A survey of the study positions and the room, when completed, formed a record on a survey form and was returned to the tabulator for compiling and filing.

The items tabulated on the form in the survey were as follows:

(1) The study room; the location of the house and of the room in the house; if the house was a fraternity or sorority, the name was given.

(2) The lamps in the room; the items noted were

(a) the total number of lamps, for both general and study-lamp illumination;

(b) the size (wattage) of the lamps at every position shown on diagram;

(c) the condition of the incandescent lamps, (amount of blackening);

(d) the location of the study lamp on the study desk, designated as right, left, center, right center, or left center;

(e) the height of the study lamp filament above the desk.

(3) The dimensions of the room; a plan of the room was drawn to show the location of the various items; the length, width, and height of the room were recorded; the floor area was calculated by the tabulator, and the watts per square foot were determined from the total wattage in the room.

(4) The reflection factor; this was determined from the color, using the color chart, and the coefficient of reflection as read from the gauge.

(5) The desk dimensions; the surface dimensions of the desk were determined by measurement.

(6) The type of study unit; the classification of room and desk units was indicated by number or by a drawing and description.

(7) The horizontal illumination on the working surface; a reading

of the horizontal illumination was taken on the desk for every foot square, and in the room for approximately every three-foot square, the points at which room readings and desk readings were taken being indicated on a diagram. Direct readings were taken for maximum and minimum foot-candles on the working surface, and the average of six readings on the plane of work was used to obtain the average foot-candles. Desk surfaces were classified as glossy or not glossy; if a desk surface had a gloss finish or a glossy auxiliary surface, "*yes*" was entered on the report form. Observation was made as to whether the desk surface reflected the light source; if a specular image of the light source was visible in the desk surface, "*yes*" was entered in the report form.

(8) An average was taken of the illumination readings on the surface faced by the student when looking up from his work.

(9) A record was made as to whether or not glasses were worn during study periods.

(10) Under remarks, any special features concerning the lighting and the general coloring of the room were noted, also any secondary glare sources.

This form is essentially the same as that developed by the committee of the Illuminating Engineering Society, with slight alterations and items added to obtain more uniform results.

3. *Data Obtained.*—The survey covered 29.0 per cent of the study surfaces used by students in residence at the local campus. The distribution of students at the time of survey was:

	Division	Enrollment	Number Surveyed	Per cent Surveyed
Men	Fraternities	2395	736	30.7
	Independent	3900	516	13.2
		6295	1252	19.9
Women	Sororities	774	397	51.3
	Residence Halls	370	337	91.0
	Independent	744	386	51.9
		1888	1120	59.3
Total		8183	2372	29.0

Since the students did not occupy separate rooms in every instance, but did have separate study surfaces, the compiled data were assem-

bled according to students for primary lighting, and according to rooms for secondary lighting. The number of students surveyed represented the following number of rooms:

	Divisions	Rooms
Men	Fraternities	424
	Independent	291
		715
Women	Sororities	316
	Residence Halls	187
	Independent	238
		741
Total		1456

The investigation of the study surface dimensions showed that 94.5 per cent of the students studied upon tables that were not comfortable because they lacked space and were not capable of being properly lighted by the use of desk lamps. A table measuring 32 inches by 54 inches is very satisfactory, since it permits the placing of the lamp in such a position as to eliminate glare and, at the same time, allows freedom for writing and the placing of reference books. A reduction of 6 inches in the width is more desirable than the same reduction in the length of the table or desk. Half of the students studied on surfaces that were 25 inches by 39 inches or less.

A study of the reflecting characteristics of the work surfaces showed that, though only 16.8 per cent of the surfaces were reported glossy, 25.7 per cent of the surfaces reflected specular images. This shows that even surfaces which appear to be satisfactory may be sources of reflected glare, very irritating to the eyes. This reflected glare will be reduced where papers and books are scattered about the desk and, frequently, the student will shift the light so that the reflected image of the lamp will be out of the range of vision.

The lighting equipment used on the study surface is one of the most important factors in proper study lighting, but the survey showed that only 4.7 per cent of the lamps used could be considered even partially satisfactory. A complete analysis of the lamps is given in Chapter II, "Investigation of Study Lamps Used by Students."

The preferred position of the study lamp, as located by the student during the work period, was on the left at the back of the work surface, as would be expected, for in this position a right-handed person can most easily remove reflected glare from the work surface.

It was noted, however, that right and center in the back, as well as center on the left side, ranked very highly.

A proper height of the light source is necessary for uniform diffusion of the light over the work surface. The committee of the Illuminating Engineering Society has found that a height of 25 inches, with the proper lighting equipment, will prove the most nearly satisfactory. It was found that 95.3 per cent of the students had light sources closer to the work surface. In few instances were the lights properly mounted.

A study was made of the work surface illumination. Values below one foot-candle were recorded as one foot-candle, because of the limitation of the measuring equipment. Experiments indicated that an average illumination of 15 foot-candles on the work surface, using a good study lamp, would be very comfortable. It was found that 64.1 per cent of the students had an average illumination of 15 foot-candles, or better, while 10.4 per cent had an illumination of 5 foot-candles, or less.

It is desirable to have from 10 to 20 per cent as much illumination on the wall surface faced as there is on the work surface, so that the seeing mechanism can be properly relaxed when the student glances up during study. An accurate method of determining this factor would be to use the ratio of the illumination on the surface faced to that on the work surface in each individual case. Only about 4.7 per cent of the surfaces studied showed a satisfactory ratio. On a basis of a satisfactory text illumination of 25 foot-candles, (10 per cent would be 2.5 foot-candles and 20 per cent would be 5 foot-candles) 59.9 per cent of the cases fell below the lower limit cited, and 77.4 per cent fell below the upper limit. It is interesting to know that the higher limit was not established by illuminating engineers, but by eye specialists. Students had observed that secondary lighting in the room improved lighting conditions, and in the upper group of 22.6 per cent the general room lighting was operated at the same time as the study lamps.

With regard to the illumination on the text or drawing which is in the immediate attention of the student during intensive study, 56.4 per cent of the surfaces examined fell below the established standard of an average of 25 foot-candles. Though the percentage of students having the correct amount of illumination was high as compared with the percentage of students having good lighting equipment, the condition prevailed that students attemped to correct the ills of poor lighting by increasing the level of illumination, often aggravating the cause of eye strain. In very few instances was the average illumination attained by proper control.

It is reported that approximately 40 per cent of students have defective eye sight, with only 18 per cent corrected. The survey showed that 42 per cent of the students used glasses when studying. This would indicate that the greater portion of the students are attempting to correct the physiological defects of the eyes, and would receive a maximum benefit, due to a reduction of the expenditure of nervous energy, by using properly controlled illumination.

A record was made of the number of lighting units found in the various rooms; this took account of all the general lighting units and the study lamps. In noting the size (wattage) of lamps used, both the study lamp and the ceiling unit were counted, for in many instances the student burned all the lighting equipment. To properly light a study surface, it is necessary to burn approximately 100 watts per position. Only 1.8 per cent of the lamps were of this wattage, a condition brought about by light-concentrating types of study lamps, and by rulings by house managers on the size of the lamp that might be used by the student. The record showed that 86.2 per cent of the lamps were in good condition, showing very little blackening; only 2.1 per cent of the lamps required replacement because of age.

In a study of the students as grouped in rooms, each student was credited with the total number of watts in the room divided by the number of students in that room, that is, in any one room, each student had the same wattage allotted to him. The survey showed that 73.1 per cent of the students were not consuming enough wattage, even if this wattage were concentrated and properly controlled. The data collected indicated that what a student lacked in lamps of large size he made up by increasing the number of lamps. Of the cases investigated 26.9 per cent had 100 watts in smaller units, but did not have the proper equipment. Only 4.7 per cent had proper study surface lighting, though 26.9 per cent could have done so with the same cost in power.

Accepting the recommended area, (70 sq. ft. per student), the allowable wattage per student for satisfactory work surface lighting would be 1.5 watts per square foot. It was found that 13.7 per cent of the students had this wattage requirement. At present, where close work of the same nature as studying is performed, 3 to 5 watts per square foot is recommended, and the school specification of the Illuminating Engineering Society recommends 3 watts per square foot. The cost of proper student work surface lighting is relatively low.

Where no room unit was found, it was usual to have the room outlet converted into a supply center, where, by multiple outlet devices, all the students connected their study lamps. Where women

students lived, it was customary to find some ornamental lamp or outlet covering used for general lighting. This latter equipment used either cloth shades or elaborately decorated parchment shades. The men students, when supplying shades to the bare lamps, turned to one of the two extremes—either a factory type of porcelain shade, or an indirect unit. Where the lighting fixture belonged to the residence, it was found to be of a direct or semi-indirect type.

Considering the general illumination of the room during the study period of the student, in only about 15 per cent of the rooms was there sufficient light to allow the student to use a dictionary or other reference. However, if the surface faced were properly illuminated, and the work surface had the right amount of illumination, correctly controlled, a low level of general illumination would not be considered unsatisfactory.

The amount of light reflected from the room surfaces will control the efficiency of the illumination and is an index to the cleanliness of the surroundings. School rooms are considered satisfactory if the ceiling has a coefficient of reflection of 70 per cent, and the lower side walls a coefficient of reflection of 50 per cent. Only 5.5 per cent of the sidewall surfaces studied fell below a reflection coefficient of 50 per cent, 14.5 per cent had 70 per cent or above. For the ceilings, only 8.7 per cent had a coefficient of reflection as large as 80 per cent, while 64.1 per cent fell below 70 per cent. The use of a study lamp designed to supply an indirect component of light would not prove satisfactory where the ceilings and side walls were permitted to absorb the greater portion of the light.

II. An Investigation of Study Lamps Used by Students

4. *Object of Investigation.*—The object of this investigation was to determine, by quantitative rather than by qualitative means, the merits of methods available to the average student for lighting study tables and desks with common lighting units. A preliminary survey of the student lighting at the University of Illinois, described in Chapter I, made in conjunction with an elective course in lighting, showed that the methods in general use for lighting student desks result in low levels of illumination, and that this poor illumination is of such quality as possibly to affect the interest in the subject matter studied, due to the consumption of nerve energy required to overcome the physiological strains.

The investigation attempts to analyze the existing lighting equipment and to show that, with little additional expense, by using available equipment, the student may improve inadequate lighting to comfortable levels under which he may study without waste of nervous energy.

An analysis is made of the new study lamp specifications of the Illuminating Engineering Society, pointing out its benefits and defects on the basis of a standardization system. The various types of study lamps used by the students are analyzed by this same standard and rated against an indirect system of lighting which would be the best possible combination that could be offered with our present systems of artificial illumination.

5. *Apparatus and Method of Investigation.*—A room in the Electrical Engineering Laboratory was fitted for the investigation with the various methods of lighting and types of equipment available to the average student. This room, which measures twelve feet six inches by sixteen feet six inches, with a ceiling height of nine feet six inches, has one door and one window which were covered with material matching the coloring of the side walls. Gray paint, comparatively fresh, but having lost its original luster, covered the side walls and the ceiling, the side walls having a reflection coefficient of 65 per cent and the ceiling a reflection coefficient of 70 per cent.

Besides incidental office equipment the room was furnished with a study table measuring 32 inches by 54 inches finished with a light oak stain and rubbed varnish. This study table was equipped with a dark green desk blotter and a group of books in ordinary sheet steel book holders. The room was so arranged that it could be completely darkened. The table was placed either in a corner, with light reflected from two walls, or against the side wall with reflected light coming from the wall faced by the student.

Auxiliary equipment for the experiments consisted of an ordinary goose-neck desk lamp, a drop light, white desk blotters, and one of the Illumination Engineering Society specification study lamps. Figure 1, reproduced from a photograph, shows the lighting equipment found in the normal study room, arranged in one of the satisfactory methods for proper lighting.

Forty foot-candle readings were taken on the desk for drawing lux plots and nine reading on the book to determine average conditions on the work surface. Observation points and various positions of the lighting equipment are shown in Fig. 2. Besides the work surface read-

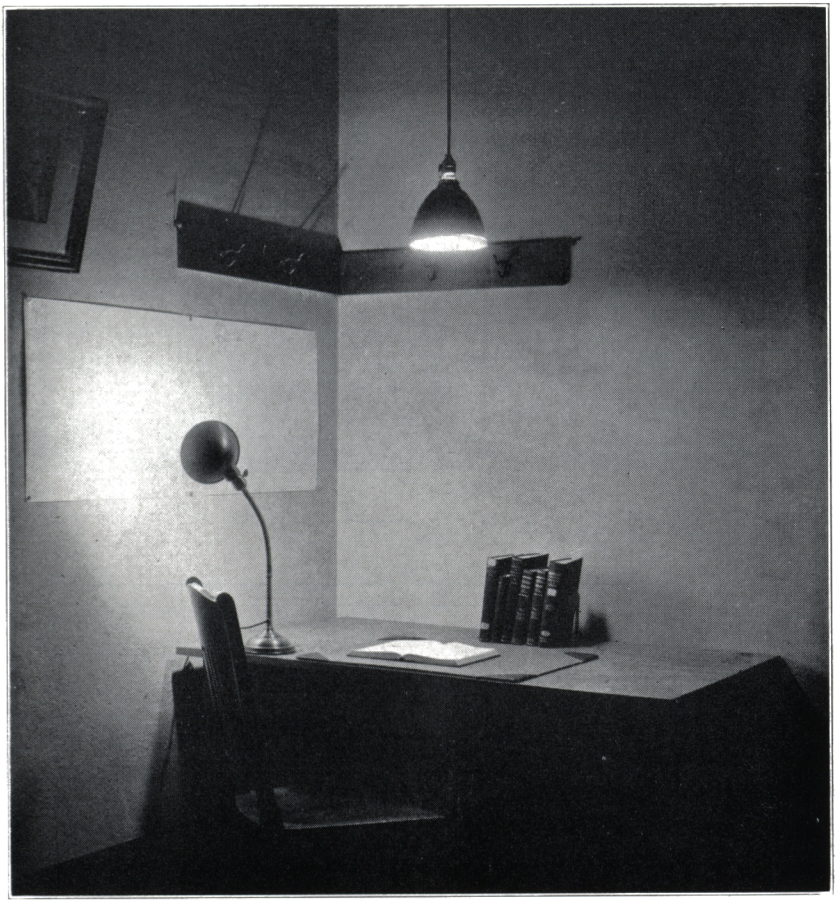


FIG. 1. EXPERIMENTAL EQUIPMENT FOR INVESTIGATION OF STUDENT STUDY LAMPS

ings, foot-candle readings were taken at thirteen points on the side wall faced by the student, at a height of eighteen inches above the surface of the desk, or approximately at the level of the eye when it is raised from the book. All foot-candle measurements were made with a Weston No. 603 foot-candle meter which eliminates the personal error of the observer, and, by having the photronic cell removed from the recording instrument, errors due to shadows and reflections.

6. *Method of Rating Study Lamps.*—The lighting equipment was rated on five equally-weighted points. This method is open to criticism, for one factor may be more directly connected with eye fatigue than another, but up to the present time no one has determined the

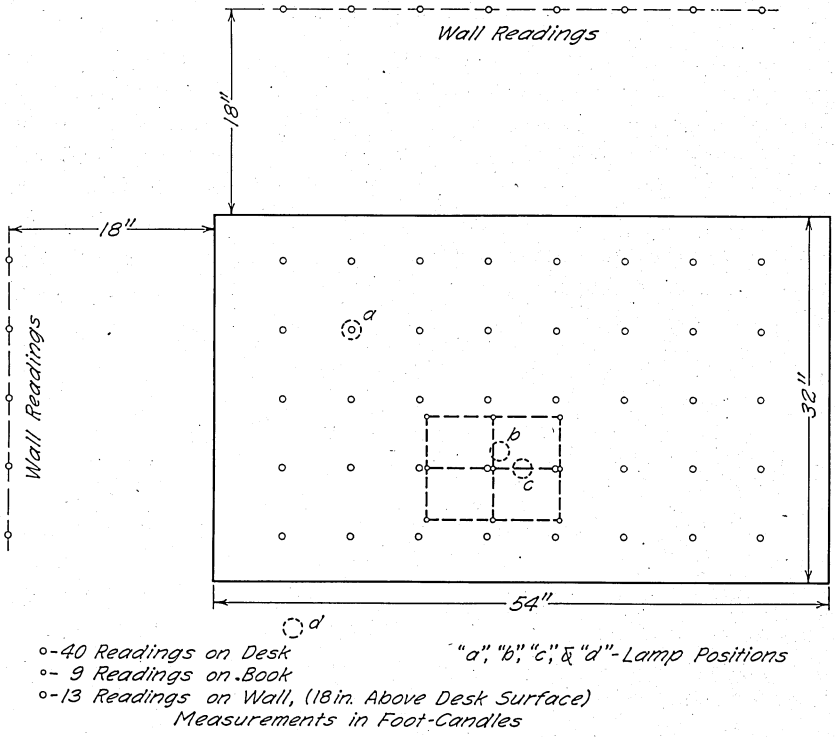


FIG. 2. STATIONS ON WALLS AND STUDY TABLE AT WHICH OBSERVATIONS WERE MADE

relative effect of the various light characteristics on the nervous energy consumed in seeing. The five factors used in rating the lamps were:

(1) Quantity of illumination (foot-candles)
  (a) On desk surface
  (b) On book surface
(2) Uniformity of illumination
  (a) On desk surface
  (b) On book surface
(3) Glare
  (a) Direct (eliminated in each study)
  (b) Indirect
(4) Shadows
(5) Ratio of wall surface illumination to work surface illumination.

The factors were graded from A to E, scaled in merit from excellent to poor.

(1) Quantity of Illumination

Since this is represented by a numerical value obtained by direct measurement with precision instruments it may be accurately determined. In agreement with general practice 30 foot-candles was chosen as the proper illumination for reading text print; any value lower than 10 foot-candles was considered unsatisfactory for easy reading. Separate ratings were given to both the desk surface and the book surface, and the "quantity of light factor" was obtained from these, the book and desk rating being proportioned as 2 to 1. The final ratings are given according to the following table:

A	30 foot-candles or more
B	25 to 29.9 foot-candles
C	20 to 24.9 foot-candles
D	15 to 19.9 foot-candles
E	10 to 14.9 foot-candles

(2) Uniformity of Illumination

This factor is determined from measured quantities, and again the book and desk surface are weighted in the ratio of 2 to 1. For an equal gain in visual effort, the amount of light utilized by the eye follows the geometric ratio, that is, equal increments of seeing require twice the amount of light. To determine the steps of illumination in the distribution on the surface the lowest value of illumination is multiplied by two and the result again by two and so on until the highest illumination is obtained. Every multiplication by two, or a part thereof, used to reach the highest value of illumination will be called a step, and these steps are rated according to the following table:

A	one step or less
B	2 to 1.9 steps
C	3 to 2.9 steps
D	4 to 3.9 steps
E	5 to 4.9 steps
Zero	more than five steps

(3) Glare

The student will ordinarily remove direct glare from any study lamp, for the effect is so irritating that equipment with a very severe direct glare is usually covered, therefore, in all the investigations on

student study lamps this factor has been eliminated. For indirect glare only three classifications have been used, namely:

A.....no specular image
B.....specular image shows diffused source
C.....specular image shows source

These ratings are determined by observing the reflection in a mirror placed in the position of the textbook.

(4) Shadows

To study the diffusion of light the rating was determined from the nature of the shadow cast by the light. For these shadow studies a piece of board, painted flat white, and with a round steel rod one-fourth inch in diameter by eight inches long, placed upright in the center, was used. This board was placed in the position of the textbook and ratings were determined according to the following scale:

A.....no shadow
C.....shadow very diffused
D.....pronounced shadow
E.....shadow with decided contrasts

(5) Ratio of Wall Surface Illumination to Work Surface Illumination

This factor was determined from the foot-candle readings by taking the ratio of the average of the eight foot-candle readings on the wall opposite the work surface to the average of the nine foot-candle readings on the book surface, and grading these ratios as follows:

A.....1 to 0.5
B.....0.49 to 0.3 or 1.1 to 1.5
C.....0.29 to 0.1 or 1.51 to 2.0
E.....less than 0.1 or more than 2.0

To determine the total rating of the lamp the letter ratings were converted to points using the following values:

A.....5 points	D.....2 points
B.....4 points	E.....1 point
C.....3 points	Zero.....0 point

These points were then averaged and converted to letter ratings as well as point ratings. By this system a perfect study lamp would rate 25 points, and the poorest, 3 points.

7. *Ratings of Various Types of Study Lamps.*—For purposes of study the lamps were divided into five classes:

(a) Ordinary goose-neck desk lamp
(b) Ordinary drop light
(c) Indirect light by using a reflector
(d) Drop light in conjunction with indirect light from a reflector
(e) Study lamp conforming to the Illuminating Engineering Society Specifications
(f) Indirect lighting fixture.

(a) Ordinary Goose-neck Desk Lamp

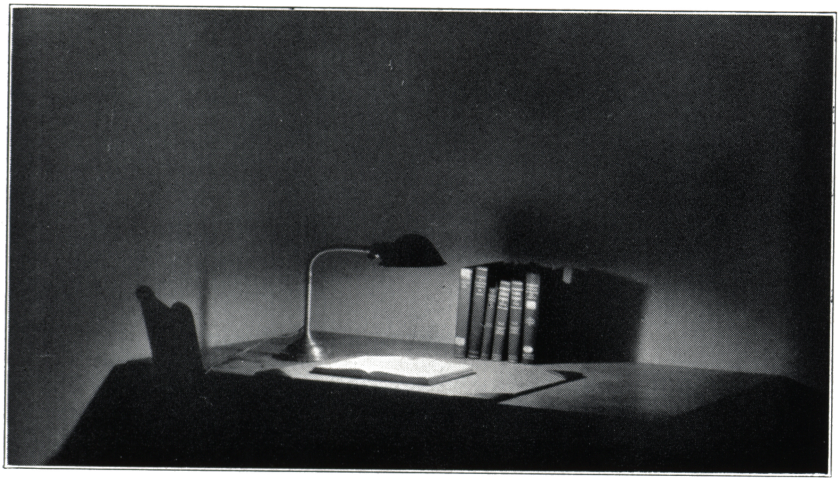
This type of lamp, which violates most of the fundamental principles of good study lamp requirements, is found in about sixty per cent of the study rooms. The only requirement which it fulfills is that of surface illumination, since even with low wattage lamps the foot-candles on the working surface exceed minimum requirements. As would be expected with such a concentrated source, the uniformity of light is very poor, and, since the direct rays of the exposed lamp fall on the working surface, glare is severe. This type of lamp causes shadows with decided contrasts, and gives little general illumination in the room, such as is essential for proper eye relaxation. A summary of the total rating by the standards established in Section 6 is as follows:

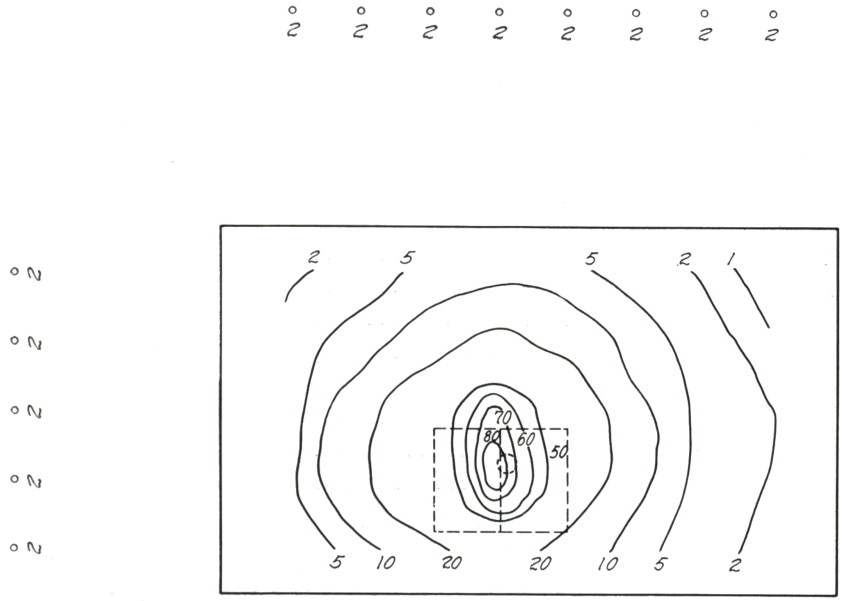
(1)	Quantity of illumination	3.7
(2)	Uniformity of illumination	2.7
(3)	Indirect glare	1.0
(4)	Shadows	1.0
(5)	Ratio of wall surface illumination to work surface illumination	1.0
	Total number of points	9.4 (out of a possible 25)
	Lighting rating	D—

Figure 3 shows the light distribution on the surface of the desk and book, and clearly demonstrates the darkness of the surrounding walls caused by the light being confined to the work surface; it also gives the lux plot on the table, and a summary of the observations made in the study of the lighting.

(b) Ordinary Drop Light

The next most common type of student desk illumination is that furnished by the ordinary type of drop light with some form of shade.





Distance of Lamp Above Surface-
11 Inches
25 w.

	Max.	Min.	Av.	Range
Desk	85	1	14.1	84
Wall	2	2	2	0
Book	160	40	85	120

Measurements in Foot-Candles

FIG. 3. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR GOOSE-NECK STUDY LAMP WITH 25-WATT BULB, 11 INCHES ABOVE WORKING SURFACE

Table placed in corner of room

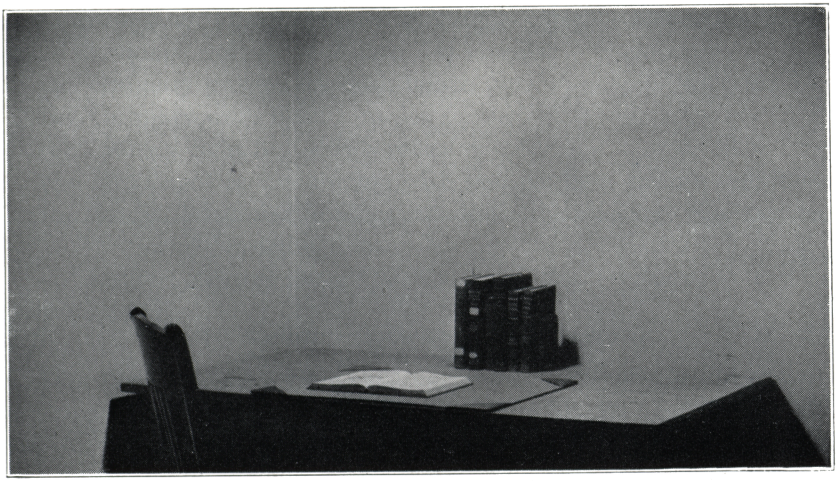


FIG. 4. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR DROP LIGHT WITH 100-WATT BULB, 45 INCHES ABOVE WORKING SURFACE

Table placed in corner of room

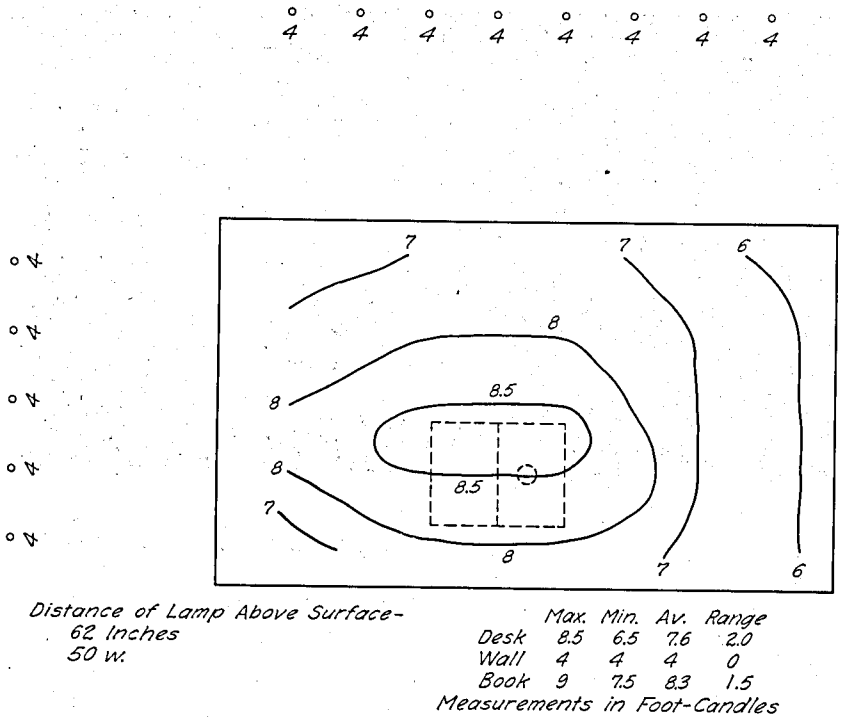


FIG. 5. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR DROP LIGHT WITH 50-WATT BULB, 62 INCHES ABOVE WORKING SURFACE

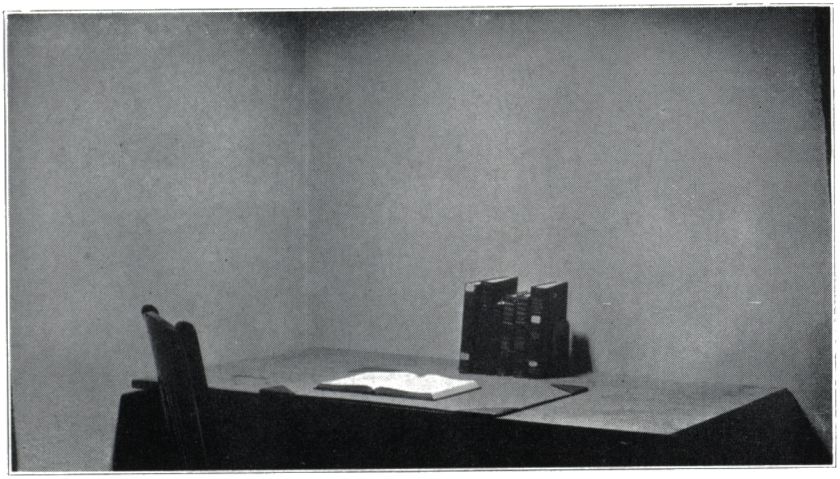
Table placed in corner of room

This type of light has advantages over the desk lamp even when no special provisions have been made to improve the character of the illumination furnished.

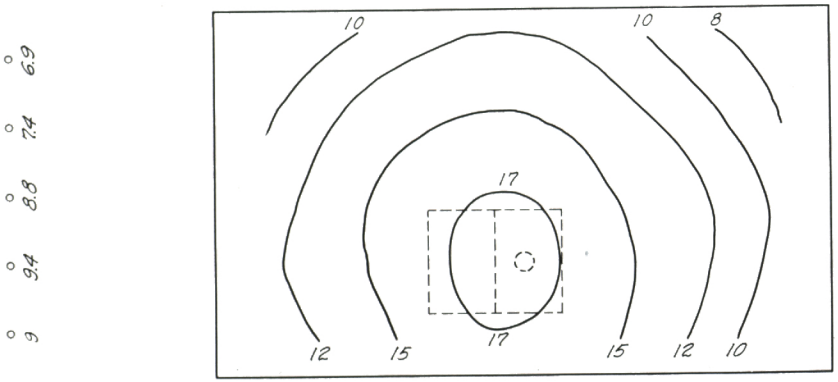
By improving the total illumination through use of lamps of the correct wattage, and by the elimination of some of the direct glare through proper screening, this type of lamp may be converted into a very satisfactory study lamp.

Figure 4 shows the results obtained by the use of a drop light with a 100-watt lamp mounted 45 inches above the working surface. This brings the illumination to about twenty-four foot-candles on the work surface. One advantage of the drop light over the desk lamp shown in Fig. 3 is the general illumination of the study room.

The lux plot in Fig. 4 shows the increase in uniformity of illumination. The most marked error found in the use of this type of equipment lies in the incorrect position of the drop light, which is usually



6 7.5 9 10.5 10 8.7 6.6 4.3



Distance of Lamp Above Surface-
45 Inches
100 w., With Tracing-Cloth
Screen.

	Max.	Min.	Av.	Range
Desk	17.0	7.8	10.6	9.2
Wall	10.5	4.3	8.0	6.2
Book	17.8	16.5	17.2	1.3

Measurements in Foot-Candles

FIG. 6. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR DROP LIGHT WITH 100-WATT BULB AND TRACING-CLOTH SCREEN, 45 INCHES ABOVE WORKING SURFACE

Table placed in corner of room

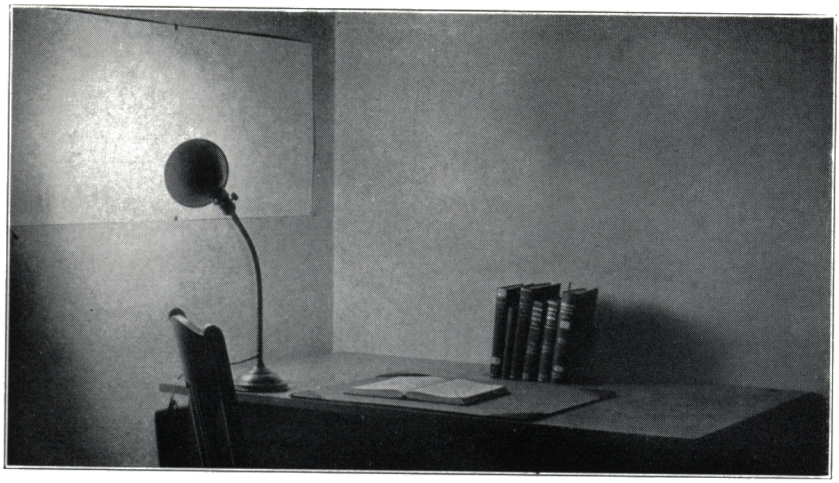
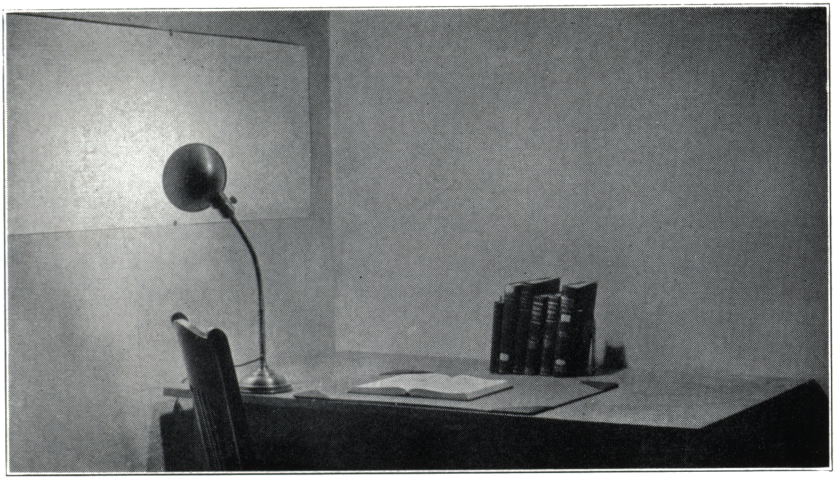


FIG. 7. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR GOOSE-NECK STUDY LAMP WITH 100-WATT BULB AND WALL REFLECTOR

Table placed in corner of room



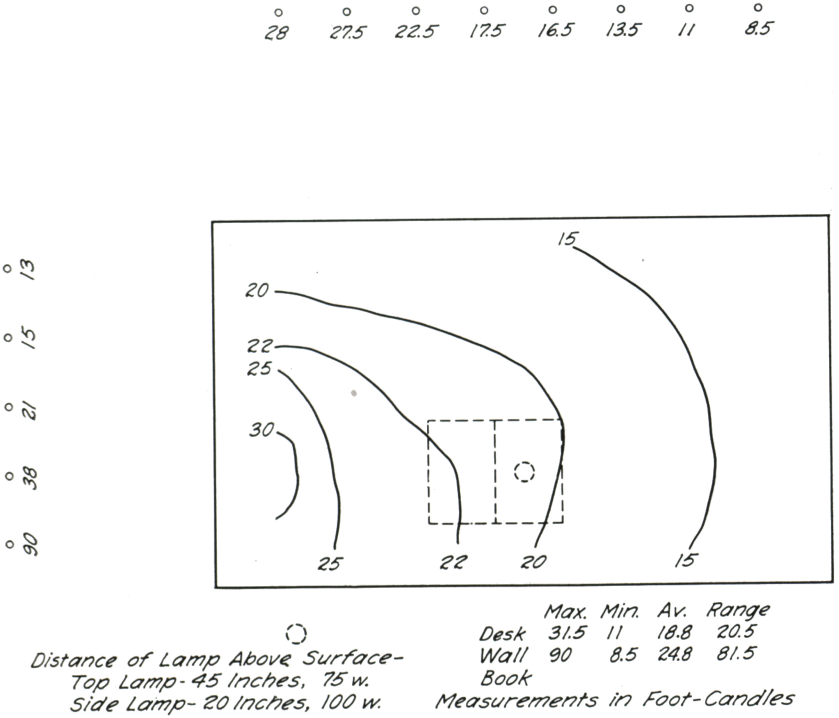


FIG. 8. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR GOOSE-NECK STUDY LAMP WITH 100-WATT BULB AND WALL REFLECTOR COMBINED WITH DROP LIGHT WITH 75-WATT BULB, 45 INCHES ABOVE WORKING SURFACE

Table placed in corner of room

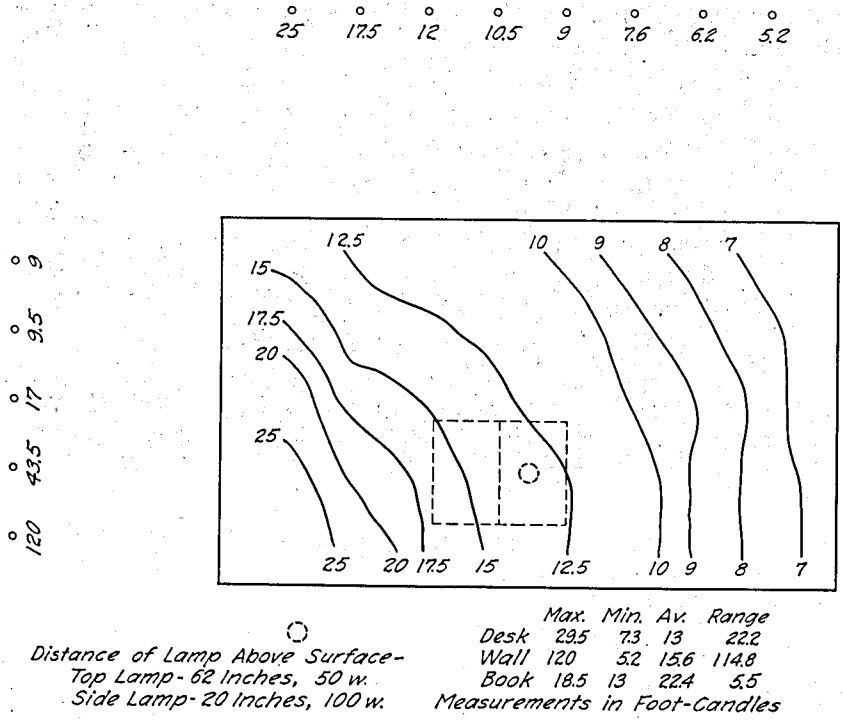


FIG. 9. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR GOOSE-NECK STUDY LAMP WITH 100-WATT BULB AND WALL REFLECTOR COMBINED WITH DROP LIGHT WITH 50-WATT BULB, 62 INCHES ABOVE WORKING SURFACE

Table placed in corner of room

placed at about the level of the top of the head of the student, so that the eyes experience direct glare from, as a rule, a 50-watt lamp each time the head is raised. Figure 5 gives the lux plot of this arrangement, using a 50-watt lamp, and with the fixture placed 60 inches above the desk. Even with this low wattage and with the fixture at this height, illumination on the surface of the desk is better than can be obtained by directing the light from a 100-watt bulb in an ordinary desk lamp against the wall, a relief method often used by students, which will be discussed later.

In order to obtain the best results from the drop light arrangement, a 100-watt lamp in the proper side reflector, either translucent or opaque, should be used. The lower portion of the reflector should be covered with two thicknesses of tracing cloth, and the fixture placed at an elevation of 45 inches above the desk. A rating of this arrange-

ment, shown in Fig. 6, by the standards chosen for this investigation, gives the following results:

(1) Quantity of illumination..... 1.7
(2) Uniformity of illumination..... 4.7
(3) Indirect glare..... 3.0
(4) Shadows..... 1.0
(5) Ratio of wall surface illumination to work surface illumination..... 4.0
Total number of points.....14.4 (out of a possible 25)
Lighting rating ..... C—

(c) Indirect Light by Using a Reflector

A number of students attempt to remove irritation caused by glare by directing the light from an ordinary desk lamp against the wall and working by the reflected light. In general this method is satisfactory, but it fails in one respect, that of *amount* of illumination. It should, therefore, never be used alone, but should be supplemented by some other light source. It is impossible to use a lamp of more than 100 watts in a goose-neck desk lamp, and with the light from even this high wattage directed against the most satisfactory reflector (white blotting paper) illumination on the work surface is still insufficient. Also, the normal wall used as a reflector is only about 50 per cent as efficient as the reflector used in this investigation, so that a student using this method of illumination would seldom obtain as good results as those obtained in the controlled study. Figure 7 and the following rating give the results of this study.

(1) Quantity of illumination..... 0.0
(2) Uniformity of illumination..... 4.3
(3) Indirect glare..... 5.0
(4) Shadows..... 3.0
(5) Ratio of wall surface illumination to work surface illumination..... 4.0
Total number of points.....16.3 (out of a possible 25)
Lighting rating ..... C+

(d) Drop Light in Conjunction with Indirect Light from a Reflector

As was stated in the foregoing paragraph, reflected light from a wall surface should be supplemented by some auxiliary light. Several combinations of arrangements were studied. Figure 8 shows the results obtained by the use of a desk lamp and wall reflector, together with a drop light placed 45 inches above the surface of the desk, with

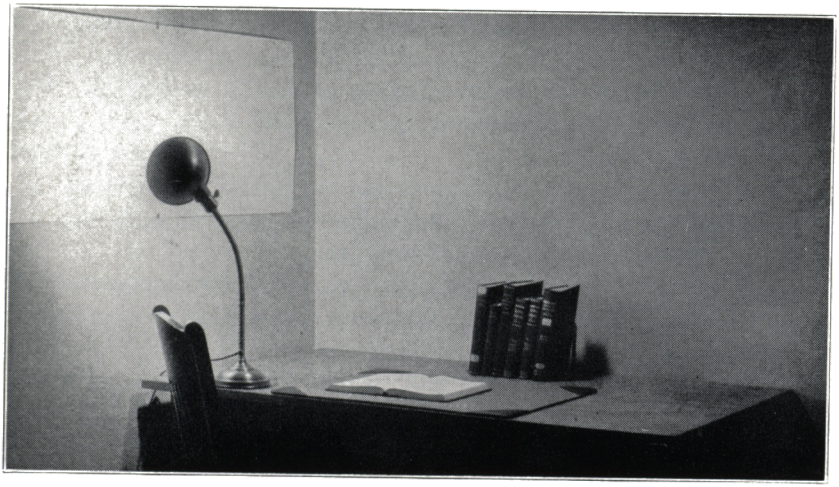


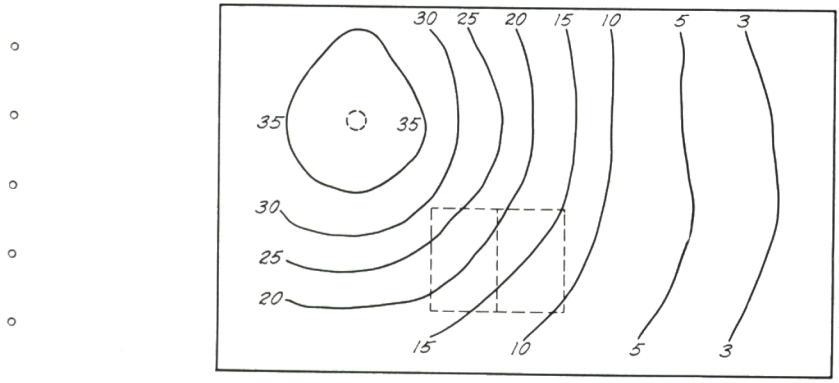
FIG. 10. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR GOOSE-NECK STUDY LAMP WITH 100-WATT BULB AND WALL REFLECTOR COMBINED WITH DROP LIGHT WITH 100-WATT BULB AND TRACING-CLOTH SCREEN, 45 INCHES ABOVE WORKING SURFACE

Table placed in corner of room

FIG. 11. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR ILLUMINATING ENGINEERING SOCIETY STUDY LAMP WITH 100-WATT BULB, 25½ INCHES ABOVE WORKING SURFACE

Table placed in corner of room

22.5 45 20.5 4 1.4 1.1 0.8 0.6



Distance of Lamp Above Surface
25½ Inches
100 w.

	Max.	Min.	Av.	Range
Desk	36	2.5	11.4	33.5
Wall	45	0.6	12	44.4
Book	26	10	16.8	16

Measurements in Foot-Candles

FIG. 12. LIGHT DISTRIBUTION ON STUDY TABLE AND SIDE WALL FOR ILLUMINATING ENGINEERING SOCIETY STUDY LAMP WITH 100-WATT BULB, 25½ INCHES ABOVE WORKING SURFACE

Table placed against side wall away from corner of room

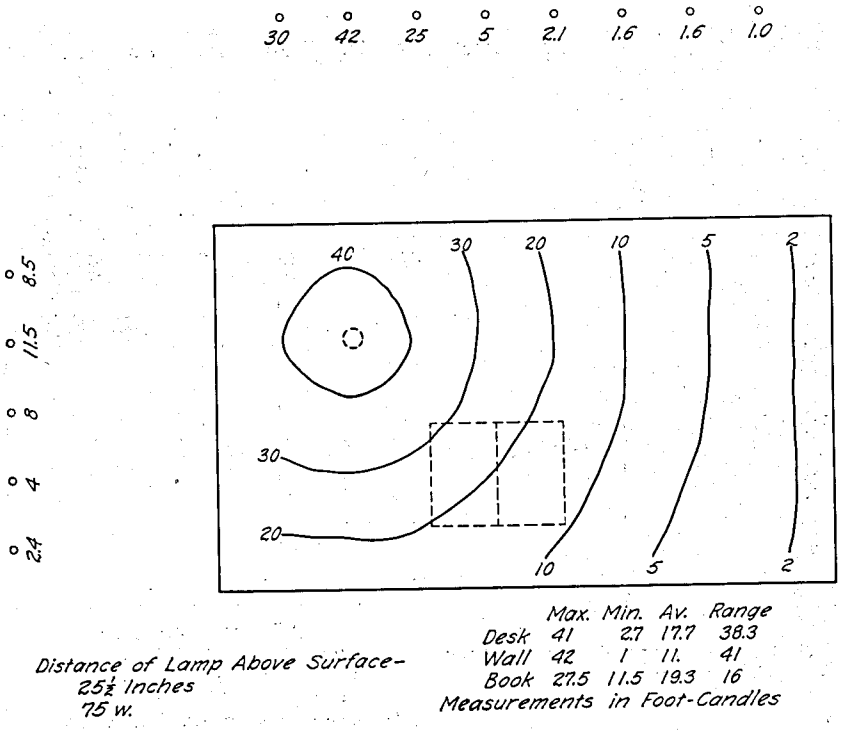


FIG. 13. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR ILLUMINATING ENGINEERING SOCIETY STUDY LAMP WITH 75-WATT BULB, 25½ INCHES ABOVE WORKING SURFACE

Table placed in corner of room

the bottom open, and using a 75-watt lamp. Figure 9 gives the lux plot when the lamp and wall reflector are combined with a 50-watt drop light placed 62 inches above the surface of the desk. Neither of these arrangements proved as satisfactory as the combination of the reflector desk lamp using a 100-watt lamp with a drop light, also using a 100-watt lamp, screened by double tracing cloth, and placed 45 inches above the desk surface. Figure 10 illustrates this latter arrangement, for which the following results were obtained:

(1) Quantity of illumination..... 2.7
(2) Uniformity of illumination..... 4.7
(3) Indirect glare..... 3.0
(4) Shadows..... 3.0
(5) Ratio of wall surface illumination to work surface illumination..... 5.0

Total number of points.....18.4 (out of a possible 25)
Lighting rating..... B—

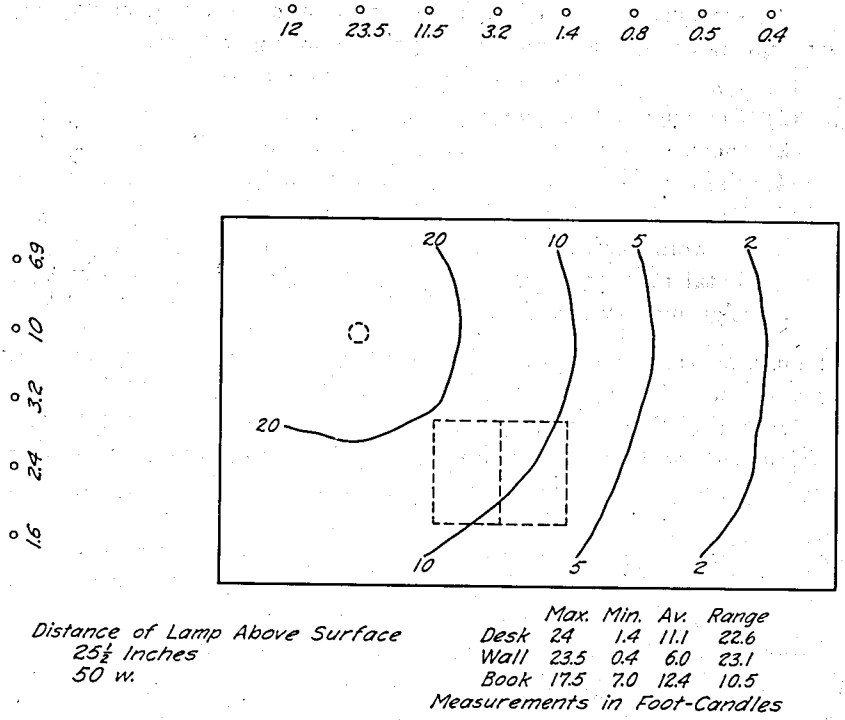


FIG. 14. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR ILLUMINATING ENGINEERING SOCIETY STUDY LAMP WITH 50-WATT BULB, 25½ INCHES ABOVE WORKING SURFACE

Table placed in corner of room

In comparing this method with the others it must be kept in mind that 200 watts were required to secure the results noted. In this discussion of lighting arrangements only the question of efficiency was considered, that of economy being disregarded.

(e) Study Lamp Conforming to the Illuminating Engineering Society Specifications

In 1934 the Illuminating Engineering Society, realizing the necessity for better lighting facilities for studying, released a specification which attempts to improve the type of lamp offered through normal trade channels to the public. In Fig. 11 one of the commercial models of this type of lamp is shown, with the study table on which the lamp stands placed in the corner of the room, while in Fig. 12 the same lamp is shown on a table placed against a side wall, thereby losing the benefit of reflected light from the second wall surface.

The arrangement subjected to analytical study was that of Fig. 11, with the table in the corner, giving the following results:

(1) Quantity of illumination..... 4.0
(2) Uniformity of illumination..... 3.0
(3) Indirect glare..... 3.0
(4) Shadows..... 2.0
(5) Ratio of wall surface illumination to work surface illumination..... 5.0
Total number of points.....17.0 (out of a possible 25)
Lighting rating ..... C+

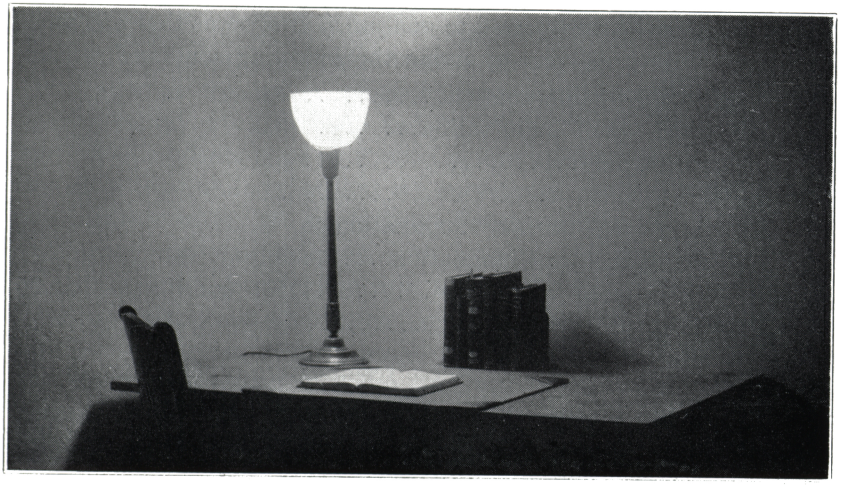
It must be kept in mind that these results were obtained by the use of a 100-watt lamp.

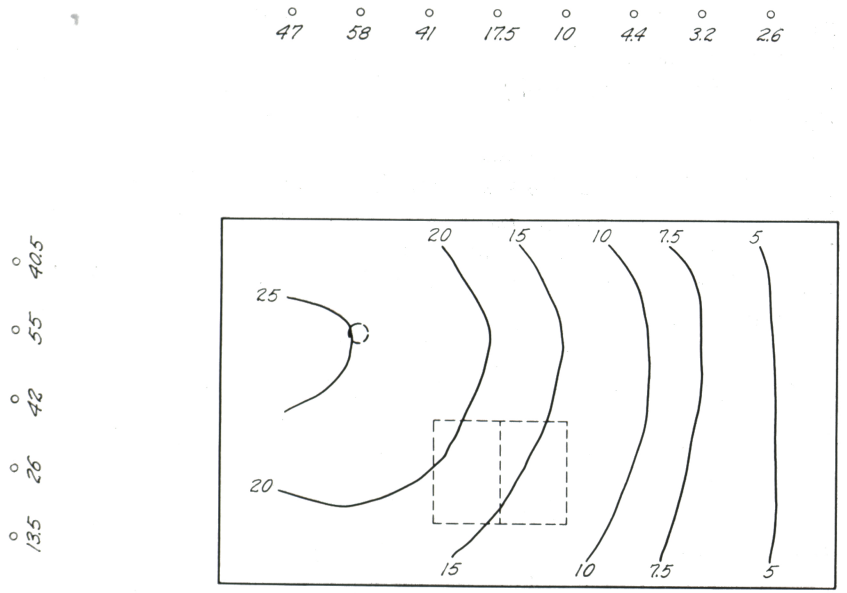
Since the I.E.S. lamp initiates a trend toward improvement of a commercial product in the interest of the conservation of human nervous energy, it was studied under various conditions in this investigation. Figures 13 and 14 show lux plots for the I.E.S. lamp using incandescent lamps of various wattages. In each instance the table was placed in the corner of the room, the position of the lamp was not changed, and the wattage of the incandescent lamp was the only variable. A study of the illumination as controlled by the component parts of the lamp was also made, and is illustrated in Figs. 15 and 16; lux plots for these arrangements are also given. In Fig. 15 the lamp is shown with the shade removed and the translucent glassware in place, while in Fig. 16 the glassware is removed, showing the bare 100-watt lamp.

(f) Indirect Lighting Fixture

The only method scoring the full 25 points was an arrangement of indirect lighting. A standard indirect lighting fixture was placed 30 inches from the ceiling over the center of the edge of the table to the right of the subject. This fixture, when equipped with a 500-watt lamp, was found to furnish the correct amount of illumination, free from glare or shadow, on the work surface, giving at the same time the proper illumination to the surrounding walls. An increase of 400 watts was necessary to obtain this increase of 8 points over the 17 points scored by the I.E.S. specification lamp, or, in other words, the lamp wattage had to be increased five times in order to obtain approximately a third more scoring points.

The data obtained are summarized in Tables 1 and 2.





Distance of Lamp Above Surface-
25½ Inches
100 w.

	Max.	Min.	Av.	Range
Desk	26.5	5.1	14.7	21.4
Wall	58	2.6	27.8	55.4
Book	20	13	17.3	7

Measurements in Foot-Candles

FIG. 15. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR ILLUMINATING ENGINEERING SOCIETY STUDY LAMP WITH 100-WATT BULB, 25½ INCHES ABOVE WORKING SURFACE, WITH SHADE REMOVED

Table placed in corner of room

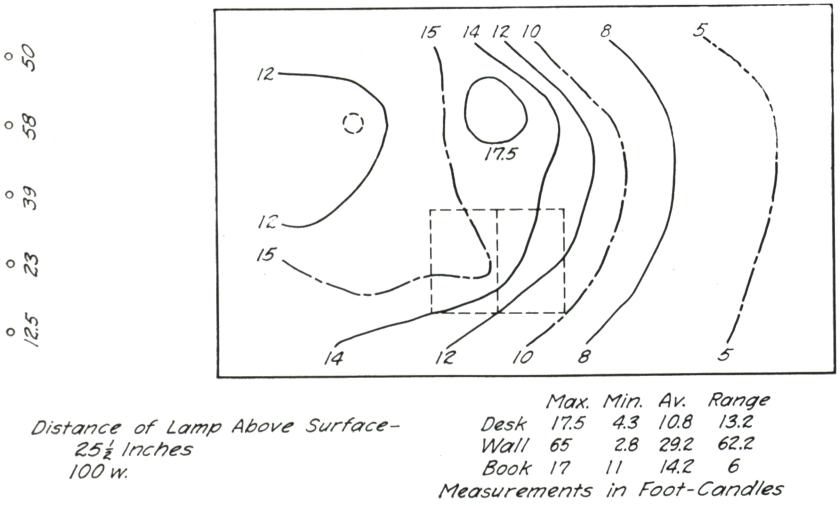


FIG. 16. LIGHT DISTRIBUTION ON STUDY TABLE AND WALLS FOR ILLUMINATING ENGINEERING SOCIETY STUDY LAMP WITH 100-WATT BULB, 25½ INCHES ABOVE WORKING SURFACE, WITH SHADE AND TRANSLUCENT GLASS REFLECTOR REMOVED

Table placed in corner of room

TABLE 1
RATINGS OF VARIOUS TYPES OF STUDY LAMPS

Type of Lamp	Wattage of Lamp	Number of Points Awarded For					Total Points Awarded	Rating
		Quantity of Illumination	Uniformity of Illumination	Glare	Shadows	Ratio of Wall Surface Illumination to Work Surface Illumination		
Goose-neck desk lamp	25	3.7	2.7	1.0	1.0	1.0	9.4	D−
Drop light with tracing cloth screen	100	1.7	4.7	3.0	1.0	4.0	14.4	C−
Goose-neck desk lamp, indirect, with wall reflector	100	0.0	4.3	5.0	3.0	4.0	16.3	C+
Goose-neck desk lamp, indirect, with wall reflector together with drop light with tracing cloth screen (100 watts each)	200	2.7	4.7	3.0	3.0	5.0	18.4	B−
Illuminating Engineering Society Specification desk lamp (desk in corner)	100	4.0	3.0	3.0	2.0	5.0	17.0	C+
500-watt indirect lamp	500	5.0	5.0	5.0	5.0	5.0	25.0	A

TABLE 2
LIGHT DISTRIBUTION WITH VARIOUS TYPES OF STUDY LAMPS

Type of Lamp	Surface	Illumination in Foot-candles			
		Maximum	Minimum	Average	Range
Goose-neck desk lamp (25 watt)	Desk	85	1	14	84
	Wall	2	2	2	0
	Book	160	40	85	120
Drop light mounted at 45 inches above desk, bottom open (100 watt)	Desk	24	13	19	11
	Wall	17	10	14	7
	Book	23	22	23	1
Drop light mounted at 45 inches above desk, with tracing cloth screen (100 watt)	Desk	17	8	11	9
	Wall	11	4	8	7
	Book	18	17	17	1
Goose-neck desk lamp, indirect, with wall reflector (100 watt)	Desk	21	3	8	18
	Wall	150	3	23	147
	Book	12	7	8	5
Goose-neck desk lamp, indirect, with wall reflector, together with drop light mounted at 45 inches above desk, with tracing cloth screen (100 watt each)	Desk	36	9	19	27
	Wall	130	7	27	123
	Book	24	20	22	4
Illumination Engineering Society Specification desk lamp (desk in corner) (100 watt)	Desk	58	2	25	56
	Wall	34	1	15	33
	Book	37	16	26	21

III. Summary

8. *Summary.*—A study of lighting conditions under which students are attempting to do their work has shown that, because of a lack of understanding of the principles involved in good illumination, practically none of them are utilizing types of lighting conducive to a desire to do mental work. The methods found in general use are almost without exception of such a character as to cause eye irritation, thereby, through wear and tear on the nervous system, setting up a physiological condition affecting concentrated thought. Improper illumination is frequently directly responsible for the drowsiness often experienced by students when attemping to study. If the points of failure of the ordinary desk study lamp were brought to the attention of the student there would no doubt be considerable improvement in the conditions mentioned. The major problem of poor lighting conditions in student rooms lies in the education of landlords and of students in general as to the principles to be observed to obtain correct lighting.

Where conservation of electrical energy is of primary importance, the drop light is better than the ordinary desk lamp and the Illuminating Engineering Society lamp offers a very much improved, if not a perfect, lighting system. Frequently the student considers nothing but the cost of the lighting equipment. The ordinary desk lamp of the goose-neck type retails at approximately one dollar, and at the same cost it would be possible to obtain a drop light which, properly placed, would give much better illumination. It is possible to convert the goose-neck type of lamp into an approved type by the addition of glassware, which may be obtained at an electric store, and a shade of proper density. The total cost of this conversion would be approximately one dollar, making the whole installation cost two dollars. The approved Illuminating Engineering Society lamp retails, in this community, at from seven and one-half dollars to as low as three dollars and eighty-five cents. Where the consumption of electrical energy is not an item to be considered, the totally-indirect equipment would be recommended.

The correction of poor lighting for the student's study desk represents a minor item in his educational cost when spread over the four-year period, and the net gain in ease of performing assigned tasks with resulting higher scholastic standings would certainly offset this cost.

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